

# QUALITY OF LIGHT: PERFECT SPECTRUM, PERFECT BEAM



With the emergence of Solid State Lighting technology, Quality of Light is taking on a new significance. Light Emitting Diodes (LEDs) based on native substrates (GaN on GaN™) make it possible for the first time to design light sources that provide unprecedented color performance and beam control- smaller, brighter, more beautiful and efficient than any previous lighting technology. Colors are rendered much more vibrantly because the basic spectrum is complete, and color consistency is superior. Smaller, brighter LEDs mean a crisp, dramatically more efficient beam, better distribution and glare control.

What do we mean by “perfect spectrum” in man-made light sources? Most of us think of daylight when we think of the perfect light source. Daylight does provide beautiful light, but must be constantly mitigated, as it contains harmful ultraviolet radiation, and can be overpoweringly bright and glaring when not controlled properly with good daylighting design in buildings. Daylight also exhibits a wide range of color temperatures and spectral qualities, depending on geographic location, time of day, and season.

In man-made light sources, a perfect spectrum is one that exhibits qualities closest to daylight- smoothness, proportion, and balance, but is ideally attuned to human sensitivity. It contains all the emissions required to render the widest range of colors in the objects we see-If the color is not contained in the light source, it is not revealed in reflectance of objects. This is a major drawback of many lighting technologies that are truncated, clipped, or deficient in key wavelengths that are important to our perception of the world around us (Figure 2).

A perfect spectrum contains only the wavelengths visible to us- no ultraviolet (UV) or infrared (IR) radiation. This makes it both beautiful and efficient, as energy is not wasted producing unnecessary heat (IR), UV radiation, or unbalanced amounts of light in different parts of the spectrum.

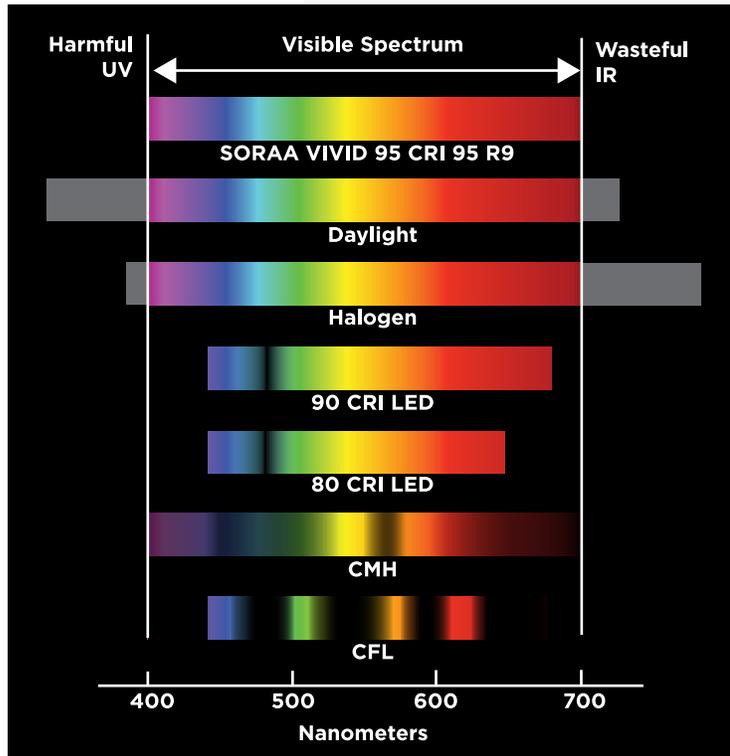


Figure 1 (top): Fruit and plate illuminated by first generation 80 CRI LED lamps (left) and SORAA VIVID 95 CRI/95 R9 lamps (right).

Figure 2 (left): Comparative Spectra of Light Sources-Many common light sources are significantly lacking in important parts of the visual spectrum, or have highly unbalanced spectral distributions. the SORAA VIVID spectrum is well balanced, with all the necessary wavelengths and none of the unnecessary ones.

# PERFECT SPECTRUM: RICHER COLORS, BRIGHTER WHITES



## Color Rendering

When light sources with low color rendering capabilities are compared side by side with perfect spectrum light sources, the difference is dramatic. Soraa Vivid lamps, with a color rendering index (CRI) of 95 and R9 (deep red rendering) of 95, provide light emission in parts of the spectrum missing from first generation Low CRI LEDs, such as deep reds, cyans, and violet. Many of the things that are most important to us in our environment- faces, food, fabrics, furniture, and finishes- contain complex colors that don't look quite right unless they are lit with perfect spectrum light containing these essential colors.

## White Rendering

An often overlooked characteristic of light sources is their ability to render white, which is arguably as important as color rendering. Most white-colored manufactured products include optical brighteners, also known as fluorescent whitening agents (FWAs), which are designed to pick up short-wavelength light (UV and violet) and re-emit it as longer-wavelength visible light (Figure 10). The effect is an increase in bluish tint as well as an increase in reflected brightness, both of which serve to make such whites "whiter". Optical brighteners have been developed over decades and are included in a wide range of materials, including clothing, cosmetics, plastics, detergents, and paper. These brighteners are excited by conventional light sources such as daylight or incandescent lamps, and they contribute to our everyday experience of white perception. Despite the ubiquity of white objects in our lives, Whiteness Rendering is not captured by standard measures of light quality, such as the Color Rendering Index (CRI).



Conventional (blue-based) LEDs cannot render such white materials properly because they lack emission of short-wavelength light that is necessary to excite the FWAs. The result is that these white materials look yellow and dingy under conventional LED lighting (Figures 7 and 8). This is a fundamental flaw in conventional LEDs, and even those with a very high CRI fail at rendering whiteness properly.



Figures 3-4 (top): Most foods and beverages contain colors in the deep red spectrum that are missing in other LED lamps (left). SORAA VIVID 95 CRI/95 R9 LED lamps (right) render food and beverages as they are meant to be seen, making them more appetizing. Figure 5: Retail directional lighting demands optimal color rendering as provided by SORAA VIVID 95 CRI/95 R9 LED lamps (right). By contrast, clothing, and accessories appear slightly drab and uninviting when illuminated by other LED lamps (left). Figure 6: Fabrics and finish materials illuminated by first generation LED lamps (left) and SORAA VIVID 95 CRI/95 R9 (right).

Soraa's GaN-on-GaN technology is engineered to render white materials with optical brighteners in exactly the same way as natural incandescence. Excitation of brighteners is provided by violet light, rather than harmful ultraviolet light. The result is a bright, white appearance optimal for modern-day clothing, cosmetics, paper products, and appliances.

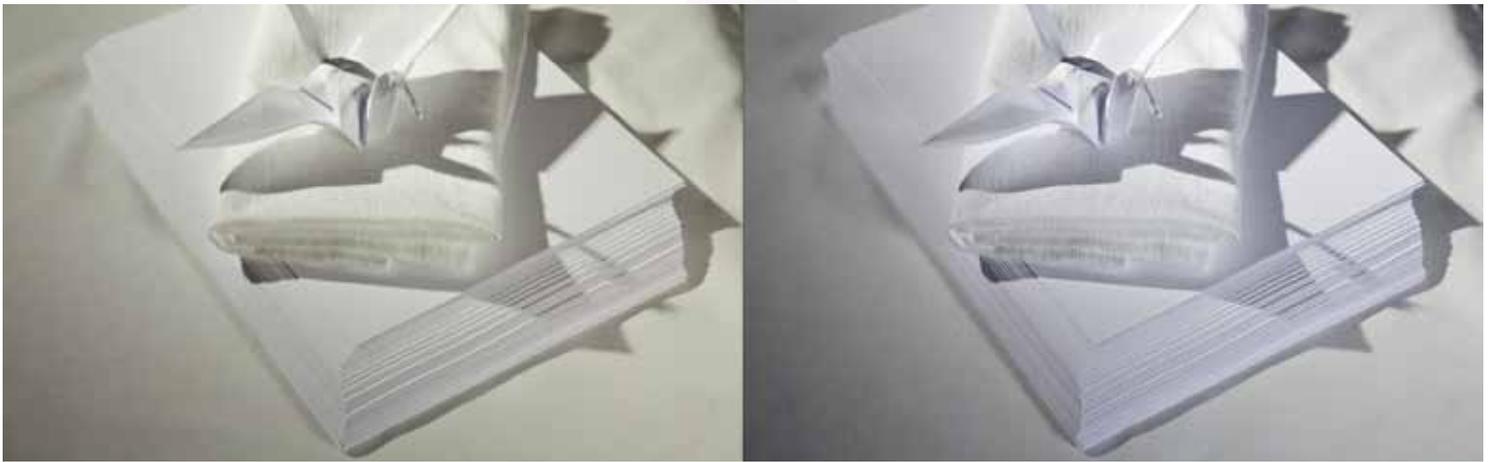
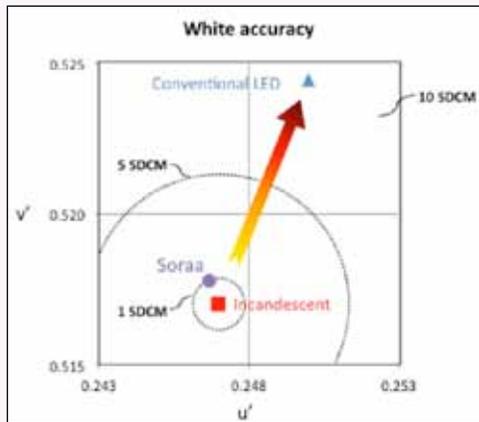
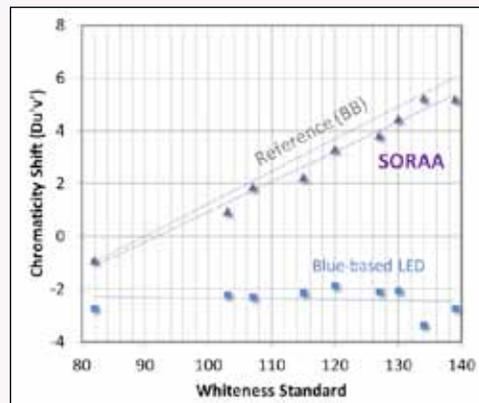
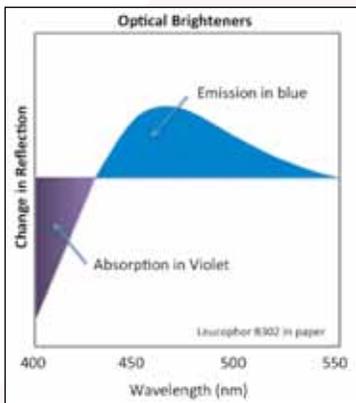


Figure 7 (top): White materials appear yellow and dingy when illuminated by other LED lamps (left). SORAA VIVID 95 CRI/95 R9 lamps (right) bring out the bright white properly. Figure 8 (above): Colors are more saturated and glowing against whiter whites, as shown in the example at right, illuminated by SORAA VIVID 95 CRI/95 R9 lamps. Other LED lamps (left) give colors and whites a less appealing appearance. Figure 9 (right): White accuracy metrics. Figure 10 (below left): how optical brighteners work. Figure 11 (below right): whiteness standards relative to the black body curve.



This was done by calculating the chromaticity shift of Whiteness Standards illuminated by a reference illuminant (e.g., 3000K blackbody emission). The slope of the chromaticity shift as a function of the Whiteness of the Standards (as specified by CIE) was then assigned a value of 100 to this slope for the reference illuminant. The Soraa lamp emission spectrum was designed to match that slope (Figure 11). For blue-based LEDs, there is no chromaticity shift (no whiteness) effect, and the slope is zero.

White Accuracy can be quantified by measuring the reflected chromaticity of white materials under natural incandescent illumination and comparing it to the case of LED illumination. As Figure 10 shows, the error in whiteness accuracy can be many SDCMs using conventional LEDs, whereas in Soraa's case, the accuracy has been engineered to be within one SDCM.



Together with the outstanding color rendering of Soraa's perfect spectrum technology, this unique ability at white rendering results in a simply perfect light source - the only LED source truly able to render all objects in a pleasant and natural fashion.

# PERFECT BEAM: CRISP SHADOWS, MINIMAL SPILL

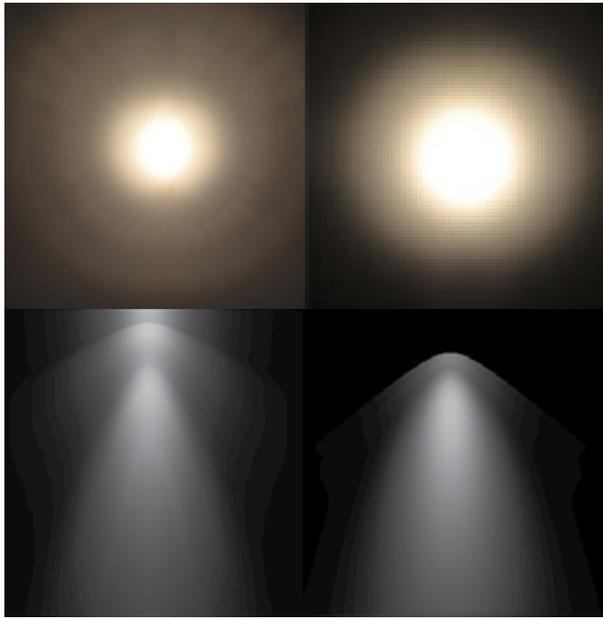


Figure 12. Left: Halogen MR16 beam. Right: Soraa LED MR16 beam.



Figure 13. Soraa lamp's single light source (right) produces a beam free of the multiple shadows and colors typical of multi-source LEDs (left).

The three components of light in directional lamps are beam, field, and spill. Beam and field are what lighting designers consider as usable lumens. Lumens falling outside this area are called "spill." Designers try to eliminate spill by using baffles, lenses and other accessories. Many LED directional lamps only concentrate on beam, and produce minimal light in the field, so they miss a key component of good lighting design. Other lamps, especially halogens, suffer from a significant amount of spill, so even if they have lumens in this area, these lumens are not considered usable (Figure 14). Most lamps have irregular beam patterns with many artifacts and poor center-to-edge color consistency. So when choosing an LED MR16 lamp, it's important to evaluate all the features of usable light, including Center Beam Candle Power (CBCP), field, beam shape, and color over angle.

Only Soraa's LED MR16 lamp delivers a perfect circular beam, with the right amount of CBCP and field, minimal spill, soft transitions and high center-to-edge color consistency.

A single LED source ensures crisp single shadows with only one color. Lamps with multiple LED sources project multiple shadows with multiple colors, yielding less attractive results on objects being displayed (Figure 13). Even halogen MR16 lamps, because they have multifaceted reflectors, do not project shadows as crisply as single LED source lamps. Soraa's single source LED MR16 lamp yields a single crisp shadow and color.

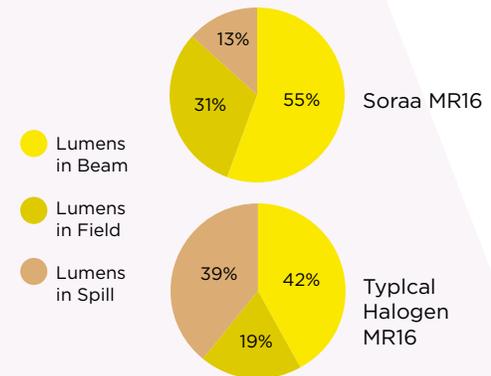


Figure 14. Typical halogen MR16s have 32% to 39% of total lumens in the spill area. Soraa MR16s have 86% of total lumens in the field and 55% in the beam. The relative amount of lumens in the beam is also 1.2x higher than the best selling LED MR16 and 1.3x higher than typical halogen MR16s.

# PERFECT FOR ALL APPLICATIONS

## Perfect Light for Food and Beverage

Deep red and cyan are particularly important for color rendering in foods and beverages, and optimal appearance can make the difference between profit and loss in hospitality and food and beverage retailing. Top chefs around the U.S are beginning to realize that perfect spectrum lighting is as important an ingredient in their success as the food itself. The superior color and white rendering of perfect spectrum light makes the colors in the food and beverages appear vivid, the tablecloths and napkins appear bright white, and the increased contrast between the brighter whites and the vivid colors makes for a rich visual experience. Perfect spectrum lighting also makes diners look (and feel) better as they dine, positively impacting the overall experience.



## Perfect Light for Retail

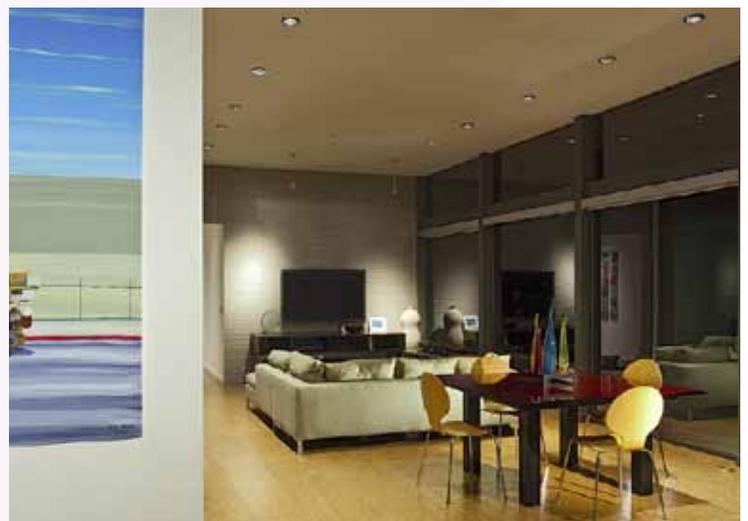
Directional display lighting is an essential part of retailing, and a wide range of products benefit from accurate and complete color and white rendering in light sources. Many high profit product categories such as cosmetics depend on customers' ability to distinguish fine gradations in color, which is only truly possible with perfect spectrum lighting. Clothing displays require perfect spectrum light to properly render their colors and whites. Other products with optical brighteners, such as paper, appliances and electronics, need perfect spectrum light to bring out their whiteness. Soraa's perfect beam renders crisp shadows in the product displays and provides a clean and inviting look to the store.



## Perfect Light for Interiors

The interiors of our homes and offices contain a wide range of colors, finishes, and materials that benefit from perfect spectrum light sources. Natural materials such as wood and fiber (as well as humans themselves) have complex and subtle coloration that only appears truly natural and vibrant under perfect spectrum light. Perfect spectrum light is also important because interior environments are usually lit by a combination of daylight and man-made light throughout the day, so man-made light closest to daylight avoids color and white mismatches and provides better consistency between day and evening lighting conditions.

Another benefit of perfect spectrum light in interiors is actually energy related. Highly efficient and comfortable lighting depends on reflectance from light colored interior surfaces, and light sources that provide better white rendering increase the efficiency of ambient light, saving energy as well as providing superior light.



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